

Takashi MIKAWA*: A taxonomic study on
Japanese sporangiferous Mucorales (6)**

三川 隆: 日本産孢子嚢性ケカビ目菌類の分類学的研究 (6)

Choanephoraceae Brefeld, Bot. Unters. Schimmelpilze 4: 161 (1881).

Vegetative hyphae creeping mostly at the surface of agar. Sporangio-phores arising from aerial mycelia or rhizoids. Sporangia present or absent, if present, columellate, not apophysate, splitting into two halves at maturity; both sporangia and sporangiola, monosporous sporangiola or "conidia" always borne on separate sporangiophores. Sporangiola, monosporous sporangiola or "conidia" borne on denticles of head vesicles, deciduous. Sporangiospores from sporangia, sporangiola, monosporous sporangiola with or without appendages at each end and "conidia" without appendages. Zygosporos globose to subglobose, formed in or at the surface of agar. Suspensors tong-like, coiling at the base.

Type genus: *Choanephora* Currey.

Some mycologists such as Fitzpatrick (1930), Zycha (1935) and Zycha *et al.* (1969) took the presence of head vesicles and sporangiola or "conidia" as taxonomic characters for separating the Choanephoraceae from the other families. However, these characters are common in the genera of the Cunninghamellaceae. In 1939 Naumov classified the Choanephoraceae sensu lat. into two families as the Choanephoraceae sensu str. and the Cunninghamellaceae mainly on a basis of sexual reproductive characters. Only *Blakeslea* and *Choanephora* were included in the Choanephoraceae. Naumov's treatment has been accepted by many mycologists such as Hesseltine (1953, 1955), Hesseltine & Benjamin (1957), Mehrotra & Mehrotra (1964) and Hesseltine & Ellis (1973).

Various disagreements remain with respect to the taxonomic position of *Rhopalomyces* and *Helicocephalum*, because no zygosporos have been found in both genera and there is no evidence regarding the existence of unisporos

* Institute of Biological Sciences, The University of Tsukuba, Sakura-mura, Ibaraki-ken 300-31, Japan. 筑波大学生物科学系.

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sporangiola or "conidia" in both genera. For example, *Rhopalomyces* was regarded as a member of the Choanephoraceae sensu lat. (Zycha, 1935; Zycha *et al.*, 1969), while this genus was placed in the Helicocephalidaceae by some mycologists such as Boedijn (1958), Ellis (1963) and Hesseltine & Ellis (1973). *Helicocephalum* was originally placed in the Helicocephalidaceae (Boedijn, 1958). This treatment has been supported by Ellis (1963) and Hesseltine & Ellis (1973). Whereas Watanabe & Koizumi (1976) treated this genus as a member of the Entomophthorales.

"Conidium" ontogeny in *Rhopalomyces* is of the botryoblast type and resembles sporogenesis of the Choanephoraceae or the Cunninghamellaceae. In my opinion, this genus is similar to *Choanephora* in superficial growth of vegetative hyphae at agar plate and pigmentation of "conidia". Therefore, this genus is placed in the Choanephoraceae in this paper. According to Barron (1976), "conidium" ontogeny in *Helicocephalum* is of the arthrospore-type. This fact may lend support to the view that *Helicocephalum* should be a genus related to members of Zoopagales.

Only one genus, *Choanephora*, has been hitherto known and found in Japan. In this paper, *Rhopalomyces* is newly added to this family.

Key to genera of the Choanephoraceae

1. Rhizoids absent. Sporangia and sporangiola or monosporous sporangiola present *Choanephora*
1. Rhizoids present. Sporangia and sporangiola absent. Only "conidia" present *Rhopalomyces*

Choanephora Currey, J. Linn. Soc. Bot. 13: 578 (1873).

Cunninghamia Currey, J. Linn. Soc. Bot. 13: 334 (1873)—*Choanephorella* Vuillemin, Bull. Soc. Mycol. Fr. 20: 28 (1904)—*Blakeslea* Thaxter, Bot. Gaz. 58: 353 (1914)—*Choanephoroidea* Miyake et Ito, Byochugai Zasshi 21: 249 (1934).

Rhizoids absent. Sporangiphores arising singly from aerial mycelia. Sporangia always present, globose. Sporangiola or monosporous sporangiola present or absent, if present, sporangiospores from sporangiola striate; monosporous sporangiola smooth or striate. Zygosporangia faintly striate. Suspensors without appendages.

Type species: *Choanephora infundibulifera* (Currey) Saccardo.

Choanephora has been thought to be distinguished from *Blakeslea* in the presence of "conidia". Whereas, *Blakeslea* has been characterized by the occurrence of sporangiola. Since Thaxter (1914) described *Blakeslea*, following discussions have been presented regarding to the existence of unispored sporangiola or "conidia" in *Choanephora*. In 1940, Shinha observed unispored sporangia in *Blakeslea trispora* and pointed out that the sporangiola in this genus are identical with the "conidia" in *Choanephora*. From this fact, Shinha treated *Blakeslea* as a synonym of *Choanephora*. Poitras (1955) demonstrated that the "conidia" in *Choanephora* possess double walls and concluded that the "conidia" in *Choanephora* are unispored sporangiola. On the other hand, Mehrotra & Baijal (1968) described a new species, *Blakeslea monospora* in which sporangiola possess one spore and sporangiolar wall can be distinguished from spore at microscope level. From the discovery of new species, they regarded *Blakeslea* as a separate genus. Recently, McWhorter & Kimbrough (1978) demonstrated the spore ontogeny of *Choanephora cucurbitara* with aid of electron microscope and confirmed that *Choanephora* possesses unispored sporangiola not "conidia". From this fact, I follow Shinha's view and treat *Blakeslea* as a synonym of *Choanephora* in this paper. In my opinion, the degree of fusion of sporangial wall and spore may be gradual transition.

Seven species have been hitherto known, in which the following four species have been found in Japan.

Key to species

1. Only sporangia present. Sporangiola or monosporous sporangiola absent *C. circinans*
1. Sporangia and sporangiola or monosporous sporangiola present 2
2. Sporangiolar walls distinguished from spores. Sporangiospores from sporangiola having appendages *C. trispora*
2. Sporangiolar walls not distinguished from spores. Monosporous sporangiola without appendages 3
3. Secondary vesicles funnel-shaped. Monosporous sporangiola smooth
..... *C. conjuncta*
3. Secondary vesicles not funnel-shaped. Monosporous sporangiola striate..
..... *C. cucurbitara*

1) *Choanephora circinans* (Naganishi et Kawakami) Hesseltine, *Mycologia* 49: 724 (1957).

Blakeslea circinans Naganishi et Kawakami, *Bull. Fac. Eng. Hiroshima Univ.* 4: 183 (1955).

Illust.: Naganishi, H. & N. Kawakami. 1955. figs. 1-9; figs. 1, a-d.

Colonies on LCA incubated at 20°C for a week hyaline, 5 mm high. Vegetative hyphae hyaline, up to 10.9 μ m wide. Gemmae formed on substrate mycelia, terminal to intercalary, single or in chain, globose, ovoid or barrel-shaped, smooth. Sporangiophores up to 12.3 μ m wide, circinate below a sporangium. Sporangia 32.2-72.5 μ m in diam., purplish brown. Sporangial walls purplish brown, roughened. Columellae obovoid to ovoid or globose, 15.9-32.7 μ m long, 14.2-19.6 μ m wide, light purplish, smooth, with a collar, not constricted at the base. Sporangiola or monosporous sporangiola absent. Sporangiospores ellipsoid to ellipsoid fusiform, 13.4-15.9 \times 5.9-7.8 μ m, light purplish. Zygospores not observed.

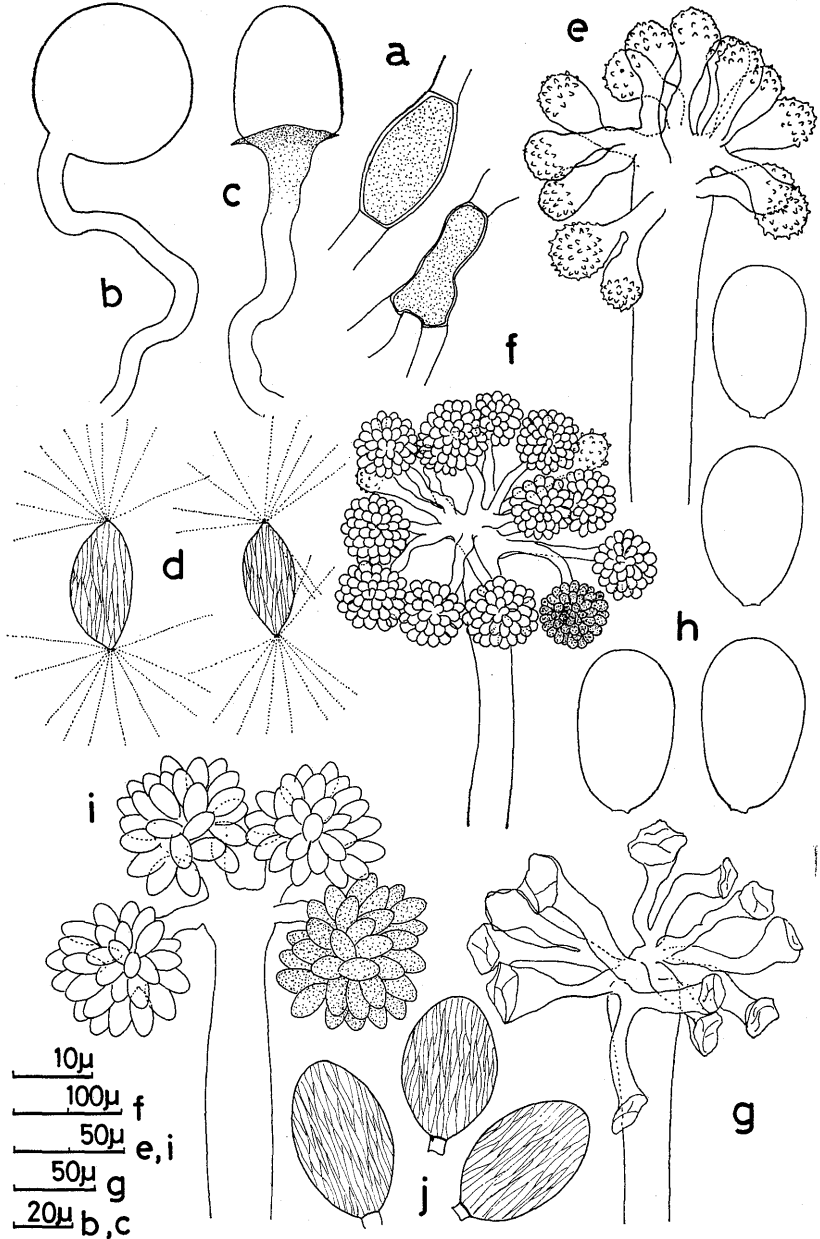
Hab. and Loc. coll.: from forest soil, Mitsune, Hachijo Isl. (Mikawa-no. 465); cultivated soil kindly collected by Dr. Koichiro Miura in Yaku Isl. (Mikawa-no. 684); pasture soil, Hiroshima Pref. (Naganishi, H. & N. Kawakami. 1955 as *Blakeslea circinans* Naganishi et Kawakami).

Zygospores have been found by Hesseltine & Benjamin (1957), Kirk (1977) and others. Notably Kirk (1977) presented the detailed account of the zygosporogenesis with aid of scanning electron microscopy.

The present isolates agree well with the original description given by Naganishi & Kawakami (1955).

This species is characterized by the presence of columellate sporangia with appendage-spores and the absence of sporangiola or monosporous sporangiola. Because of the absence of sporangiola or monosporous sporangiola, the taxonomic position of this species have been remained to be solved by many mycologists. Naganishi & Kawakami (1955) included their fungus in *Blakeslea*. Later in 1957, Hesseltine & Benjamin transferred it to *Choanephora* on the basis of the resemblance to zygospores of *Choanephora*.

Fig. 1. a-d. *Choanephora circinans*. a. Gemmae. b. Young sporangium. c. Columellae. d. Sporangiospores having appendages. e-h. *Choanephora conjuncta*. e. Early stage of monosporous sporangiola formation. f. Sporangiphore bearing monosporous sporangiola. g. Head vesicles left after detachment of monosporous sporangiola. h. Monosporous sporangiola. i, j. *Choanephora cucurbitarum*. i. Sporangiphores bearing monosporous sporangiola. j. Monosporous sporangiola.



- 2) **Choanephora conjuncta** Couch, J. Elisha Mitchell Sci. Soc. 41: 143 (1925).
Illust.: Naganishi, H. & N. Kawakami. 1955. Pls. 1, 2, figs. 1-20; figs. 1, e-h.

Colonies on LCA incubated at 20°C for a week hyaline, up to 1 cm high. Vegetative hyphae hyaline, up to 19.2 μm wide. Gemmae formed on substrate or aerial mycelia, intercalary, single or in chain, ovoid, barrel-shaped or fusiform, smooth. Sporangiophores up to 9.8 μm wide, straight or circinate below a sporangium. Sporangia 25-50 μm in diam., dark purplish. Sporangial walls pale purplish, roughened. Columellae obovoid, globose or applanate, 13.3-29.6 μm long, 13.3-21.4 μm wide, hyaline to pale purplish, smooth, with a collar, not constricted at the base. Sporangiospores ellipsoid, 12.4-18.6 \times 8-11.4 μm , pale purplish, smooth. Sporangiophores of monosporous sporangiola up to 46 μm wide ending into a primary head vesicle which produces secondary vesicles; the secondary vesicles funnel-shaped after monosporous sporangiola detached. Monosporous sporangiola ovoid, 13.4-23.8 \times 10.6-13.8 μm , pale purplish, smooth, with papilla at one end. Zygosporangia not observed.

Hab. and Loc. coll.: from fallen flower of *Hibiscus*, Noda, Saitama Pref. (Mikawa-no. 916); fallen flower of canna, Otsuka, Tokyo (Mikawa-no. 911); fallen flower of *Hibiscus*, Koishikawa Botanical Gardens, Tokyo (Mikawa-no. 917); faded flowers of dahlia, cosmos, squash, cucumber, canna, morning glory, Hiroshima Pref. and coastal regions along the Inland Sea of Japan (Naganishi, H. & N. Kawakami. 1955 as *C. infundibulifera* (Currey) Cunningham).

Zygosporangia have been found by Hesseltine (1953), Naganishi & Kawakami (1955), Hesseltine & Benjamin (1957) and Mehrotra & Mehrotra (1964).

The present isolates agree well with the original description and that given by Naganishi & Kawakami (1955).

This species is similar to *C. infundibulifera* in the presence of funnel-shaped head vesicles and characters of zygosporangia but differs from the latter in the following features: 1) monosporous sporangiola of *C. conjuncta* are smooth, while those of *C. infundibulifera* are striate, 2) monosporous sporangiola of *C. conjuncta* are ovoid, whereas those of *C. infundibulifera* are ovoid to ellipsoid.

Naganishi & Kawakami (1955) reported *C. infundibulifera* and presented the detailed morphological account of this species. Later in 1957, however,

Hesseltine & Benjamin reexamined carefully Japanese isolates of *C. infundibulifera* received from IFO and pointed out that Japanese isolates of *C. infundibulifera* are identical with *C. conjuncta*. Judging from the description and illustrations given by Naganishi & Kawakami (1955), the treatment of Hesseltine & Benjamin is accepted by the present author in this paper.

3) **Choanephora cucurbitaria** (Berkeley et Ravenel) Thaxter, *Rhodora* 5: 102 (1903).

Rhopalomyces cucurbitarum Berkeley et Ravenel, *Grevillea* 3: 109 (1875)—*R. elegans* Corda var. *cucurbitarum* Marchal, *Rev. Mycol.* 15: 11 (1893)—*Choanephora americana* Moeller, *Phycomycet. & Ascomycet.* 393 (1901)—*Choanephorella cucurbitarum* Vuillemin, *Bull. Soc. Mycol. Fr.* 20: 28 (1904)—*Cunninghamella mandshurica* Saito et Naganishi, *Bot. Mag. Tokyo* 29: 285 (1915)—*Choanephora mandshurica* (Saito et Naganishi) Tai, *Sinensia* 4: 219 (1934)—*Choanephoroidea cucurbitae* Miyake et Ito, *Byochugai Zasshi* 21: 249 (1934).

Illust.: Miyake, I. & S. Ito. 1934. figs. 3-6; Naganishi, H. & N. Kawakami. 1955. Pls. 1, 2; Nishihara, N. 1968. figs. 1, 2; Nishihara, N. & I. Misono. 1956. fig. 8; Yoshida, M. 1950. Pls. 1, 2; figs. 1, i, j.

Colonies on LCA incubated at 20°C for a week, hyaline, 1 cm high. Vegetative hyphae hyaline, up to 11.5 μ m wide. Gemmae formed on substrate or aerial mycelia, intercalary, single or in chain, globose, ovoid or barrel-shaped, smooth. Sporangiophores up to 14.8 μ m wide, straight or circinate below a sporangium. Sporangia 25-75 μ m in diam., purplish brown. Sporangial walls purplish brown, roughened. Columellae obovoid, pyriform or applanate, 15-31.8 μ m long, 14.3-25 μ m wide, hyaline to pale purplish, smooth, with a collar, not constricted at the base. Sporangiospores ovoid to ellipsoid, 16.3-24 \times 7.5-13.3 μ m, hyaline to pale purplish, faintly striate. Sporangiophores of monosporous sporangiola up to 23.3 μ m wide ending into a primary head vesicles which usually produce secondary vesicles. Monosporous sporangiola ellipsoid, 16.6-20 \times 11.6-12.5 μ m, purplish brown, striate, with a papilla at one end, without appendages. Zygospores not observed.

Hab. and Loc. coll.: from fallen flower, Arai, Saitama Pref. (Mikawa-no. 945); fallen flower of *Hibiscus*, Koishikawa Botanical Gardens, Tokyo (Mikawa-no. 947); straw of rice plant, Hokkaido (Ito, S. 1932, 1936); flower and fruit of squash, Tokyo (Miyake, I. & Ito, S. 1934 as *Choanephoroidea cucurbitae* Miyake et Ito); faded flowers of dahlia, cosmos, squash, cucumber,

canna, morning glory, Hiroshima Pref. and coastal regions along the Inland Sea of Japan (Naganishi, H. & N. Kawakami. 1955); Ladino clover (*Trifolium repens*), Kagoshima and Saga Pref. (Nishihara, N. 1968); fruit of squash, Chiba Pref. (Nishihara, N. & I. Misono. 1956); leaf of sugar beet, Okayama Pref. (Yamauchi, K. & S. Fujii. 1962 as *Choanephora* sp.); leaf of pea, Okayama Pref. (Yoshida, M. 1950).

Zygospores have been found by Hesseltine (1953), Naganishi & Kawakami (1955), Hesseltine & Benjamin (1957) and Mehrotra & Mehrotra (1964).

The present isolates agree with the description given by Naganishi & Kawakami (1955).

This species is distinguished from *C. conjuncta* by the absence of funnel-shaped vesicles and the occurrence of striate sporangiola.

C. cucurbitara is an economically significant fungus because of causing disease in several vegetables. Therefore, from phytopathological aspects, investigations on *C. cucurbitara* have been made by many Japanese mycologists such as Miyake & Ito (1934), Yoshida (1950), Nishihara (1968) and others. Miyake & Ito (1934) found a fungus, causing a disease of squash and described it as a new genus, *Choanephoroidea*, based on *C. cucurbitae* in which the sexual reproduction occurs by the formation of oogonium and antheridium. However, the characteristics of sexual reproduction is inadequately described without figures of developmental stages of oospore. Judging from the description of asexual reproductive characters, *C. cucurbitae* is identical with *C. cucurbitara* and should be reduced to a synonym of *C. cucurbitara*. Therefore, the genus *Choanephoroidea* is merged in *Choanephora*. Yamauchi & Fujii (1962) found *Choanephora* sp. attacking leaves of sugar beets and causing *Choanephora* Rot (kekabi byo) at the seat of infection. From the description given by them, this fungus is identified as *C. cucurbitara*.

Rhopalomyces cucurbitarum Berk. et Ravenel, when transferred to the genus *Choanephora*, was called *Choanephora cucurbitarum* (Berk. et Ravenel) Thaxter. However, the epithet '*cucurbitarum*' should be changed to *cucurbitara* on a basis of Article 23 of the International Code of Botanical Nomenclature.

- 4) ***Choanephora trisporea*** (Thaxter) Shinha, Proc. Indian Acad. Sci. Sect. B. 11: 167 (1940).

Blakeslea trisporea Thaxter, Bot. Gaz. 58: 353 (1914)—*Choanephora di-*

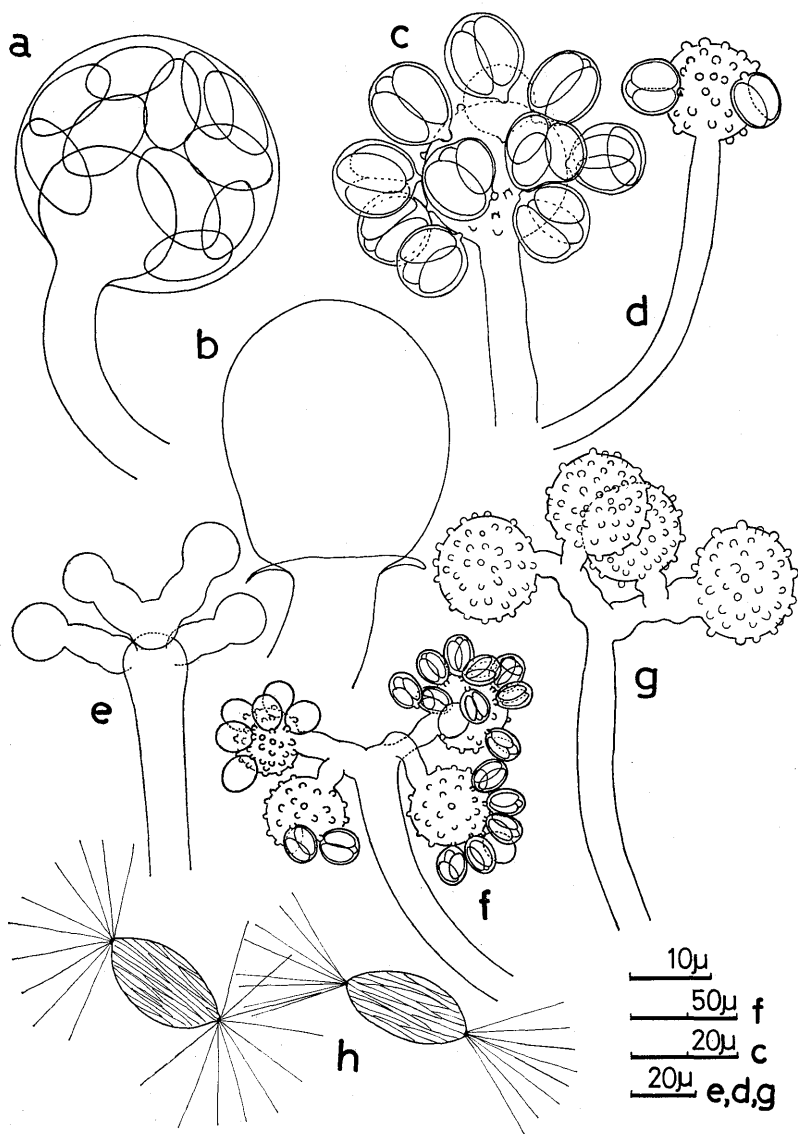


Fig. 2. a-h. *Choaneophora trispora*. a. Sporangium having a columella and sporangiospores. b. Columella. c, d. Primary head vesicles bearing sporangia. e. Early stage of secondary head vesicles development. f. Secondary head vesicles bearing sporangia. g. Secondary head vesicles left after detachment of sporangia. h. Sporangiospores having appendages.

chotoma Gandrup, Besoek. Proefstat. Medel. 3 : 5 (1923).

Illust. : Naganishi, H. & N. Kawakami. 1955. figs. 1-15; figs. 2, a-h.

Colonies on LCA incubated at 20°C for a week, hyaline, 5 mm high. Vegetative hyphae hyaline, up to 19.2 μ m wide. Gemmae formed on substrate or aerial mycelia, intercalary, single or in chain, ovoid, barrel-shaped, smooth. Sporangiphores up to 32.3 μ m wide, circinate below a sporangium. Sporangia 30-60.5 μ m in diam., purplish brown. Sporangial walls pale purplish, roughened. Columellae obovoid or dome-shaped, 22.8-28 μ m long, 22-32.8 μ m wide, hyaline to pale purplish, smooth, with a collar, not constricted at the base. Sporangiphores of sporangiola up to 45.5 μ m wide, ending into a primary head vesicles or branched dichotomously at the apex; its branches ending into secondary vesicles. Head vesicles bearing sporangiola. Sporangiola ovoid, 16.4-18.5 \times 15.5-17 μ m, usually containing 3-spores, rarely 1 or 5 spores. Sporangiolar walls hyaline, smooth, breaking. Sporangiospores from sporangia and sporangiola ellipsoid to fusiform ellipsoid or ovoid, 15.6-17.2 \times 7.5-8 μ m, purplish brown, striate. Zygospores not observed.

Hab. and Loc. coll. : from cultivated soil, Ashigakubo, Saitama Pref. (Mikawa-no. 263); soil kindly collected by Miss Shizu Kuzuha in Nara Park, Nara Pref. (Mikawa-no. 78); air, Mt. Jodo-san, Toyama Pref. (Naganishi, H. & N. Kawakami. 1955 as *Blakeslea trispora* Thaxter).

Zygospores have been found by some mycologists including Naganishi & Kawakami (1955).

The present isolates agree with the original description and that given by Naganishi & Kawakami (1955).

This species is distinguished from other species of *Choanephora* by having 3-spored sporangiola usually. The detailed morphological account of this species was presented by Naganishi & Kawakami (1955).

Rhopalomyces Corda, Prachtflora, 3 (1839).

Rhizoids present. Sporangiphores arising singly from substrate mycelia, aerial mycelia or rhizoids, brownish. Sporangia and sporangiola absent. Only "conidia" present. Zygospores unknown.

Approximately 13 species have been hitherto known, in which only one species has been found in Japan.

Rhopalomyces strangulatus Thaxter, Bot. Gaz. 16 : 14 (1891).

Illust. : Tubaki, K. 1973. Pl. 4, figs. A-D.

Hab. and Loc. coll.: from decaying animal material with old bones, Shugakuin, Kyoto (Tubaki, K. 1973).

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Choanephoraceae に所属する 2 属 5 種を報告した。Blakeslea と Choanephora は従来小孢子囊をもつか分生子をもつかにより識別されていたが、近年 Choanephora の分生子は 1 孢子性の小孢子囊であることが電子顕微鏡による観察で明らかにされたので (McWhorter & Kimbrough, 1978)、本論文では Shinha (1940) の見解に従って Blakeslea を Choanephora の同属異名として扱った。長西と川上 (1955) は Choane-

phoraceae の分類学的研究の中で日本産の *Choanephora* の菌株に *C. infundibulifera* の学名を使用した。彼らの記載と図及び日本産の菌株を検討した結果、長西と川上の *C. infundibulifera* は *C. conjuncta* に一致することが判明した。三宅と伊東 (1934) はカボチャの軟腐病の病原菌に新種名 *Choanephoroidea cucurbitae* を与え新属 *Choanephoroidea* を設立した。今回、三宅と伊東の原記載と図に基づいて本種を検討した結果、*C. cucurbitae* を *Choanephora cucurbitaria* の同種異名とし、*Choanephoroidea* を *Choanephora* の同属異名として扱うことが妥当と結論した。

○Materials for the distribution of lichens in Japan (6) 地衣類分布資料 (6)

○*Cornicularia odontella* (Ach.) Röhl. Although the present species represents a circumpolar distribution, being known from Europe, Siberia, and North America, it has been recorded from only one locality (Mt. Iide, Prov. Uzen) in Japan (Sato, Journ. Jap. Bot. 15: 573. 1939 and 16: 117. 1940). Two new localities in Japan are herewith reported for this species as follows. In these localities, *C. odontella* grows on granites in the *Pinus pumila* zone.

Specimens examines. Toyama Prefecture: Mt. Etchusawa-dake, Tateyama Mts., elevation about 2400 m, K. Yoshida 2016 (TNS) and H. Kashiwadan 13406 (TNS). Nagano Pref.: Mt. Kimpu, Minami-Saku-gun, elevation about 2590 m, K. Yoshida 3028 (TNS).

佐藤正巳博士 (1939, 1940) が飯豊山において本種を発見したのが、日本における唯一の記録であった。ところが最近、本州の 2 地点、富山県越中沢岳および長野県金峰山で本種を発見した。何れもハイマツ帯の露出した花崗岩上に生育していた。本種の地衣体は小さく (通常 1 cm 以下)、同じような黒褐色の地衣体をもつクリロトゲキノリなどと混生しているため見逃しやすいが、尾根筋の岩上に広く分布しているように思われる。 (吉田考造)

□広瀬嘉道・横井政人: 原色斑入り植物写真集 (ガーデンライフ別冊) 211 pp. 内 128 カラープレート。1978 年 11 月。誠文堂新光社。¥ 3600。種々な斑入りの写真集と名彙とをかねたもの。はじめに斑の形式を図示し、分類順に写真をおき、リストでは和名と学名及び斑の型列を附記してある。バイラスによるかと思うものは加え、一方、本来斑入りのもの、たとえばカンアオイ、ミヤマウズラなどやオモト、フウランなどは制限乃至除かれている。斑入りは個体を沢山集めれば必ずずといってよいほど見つかるが、さりとてそうは出合わないのが現状。徳川時代には草木奇品家雅見のような類書もあったが、美しい写真と細密な世界的リストが揃ったのははじめてであろう。記事にも中々思い切った方法がのべてあるのも面白い。 (前川文夫)